

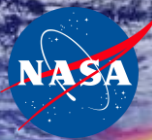


From the A-Train to National Objectives - and Back

Jack A. Kaye

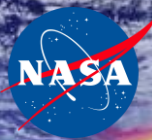
**Earth Science Division
Science Mission Directorate
NASA Headquarters**

October 27, 2010



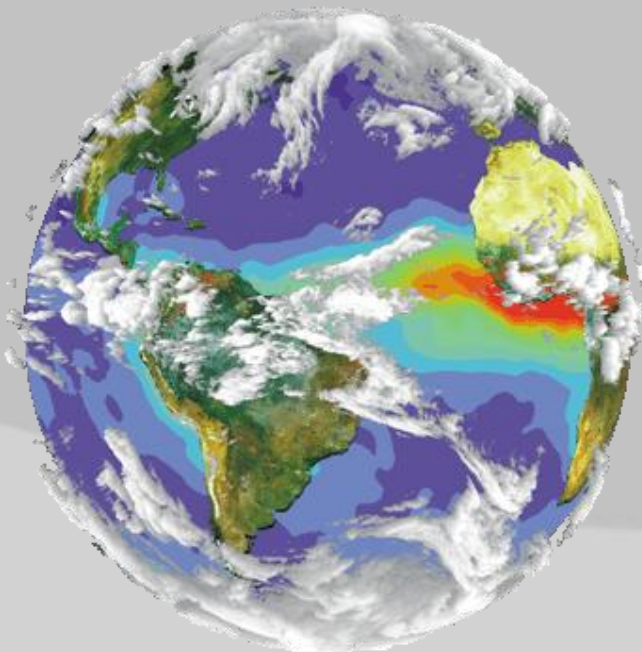
Outline of Talk

- The Goals of NASA's Earth Science Program in the National Perspective
- The A-Train in the Integrated NASA Earth Science Research Program
- Future Evolution of Federal Earth Science Research and Implications for NASA



Earth as a Dynamic System

Forces acting on
the Earth system



Earth system
responses

IMPACTS

Feedbacks

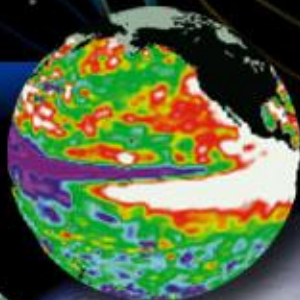


NASA

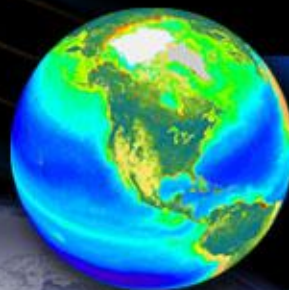
Earth Science Division

Research and Analysis Focus Areas

Climate Variability
and Change



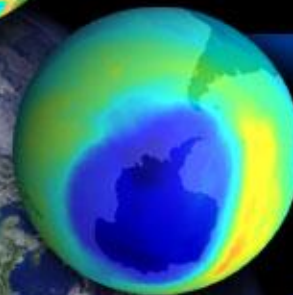
Carbon Cycle
and Ecosystems



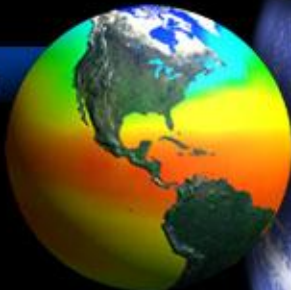
Earth Surface
and Interior



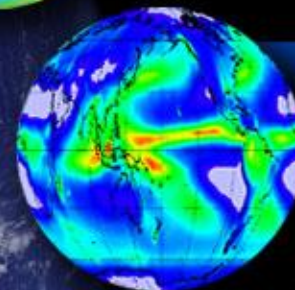
Atmospheric
Composition

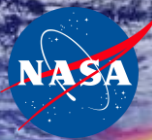


Weather

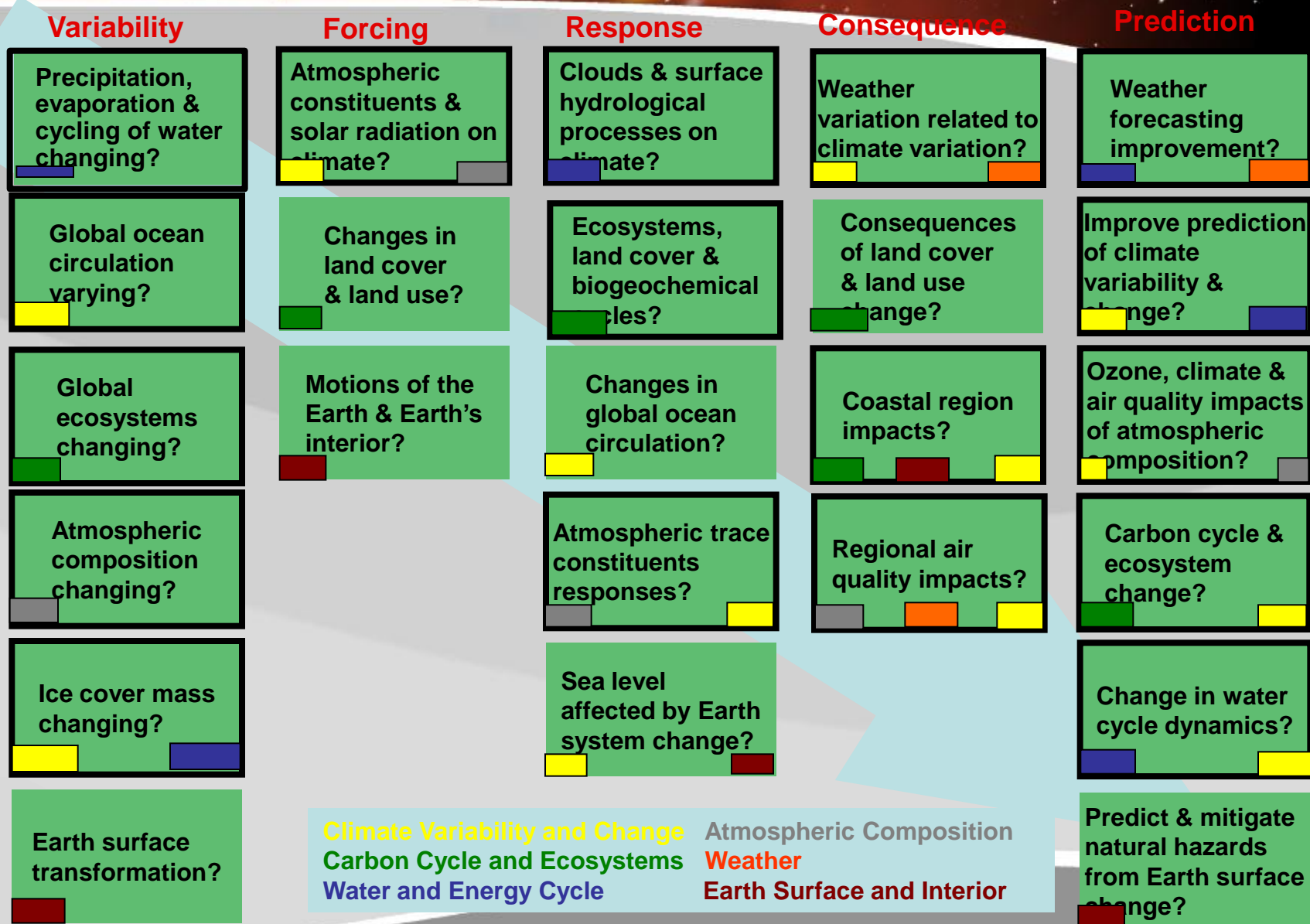


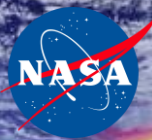
Water &
Energy
Cycle





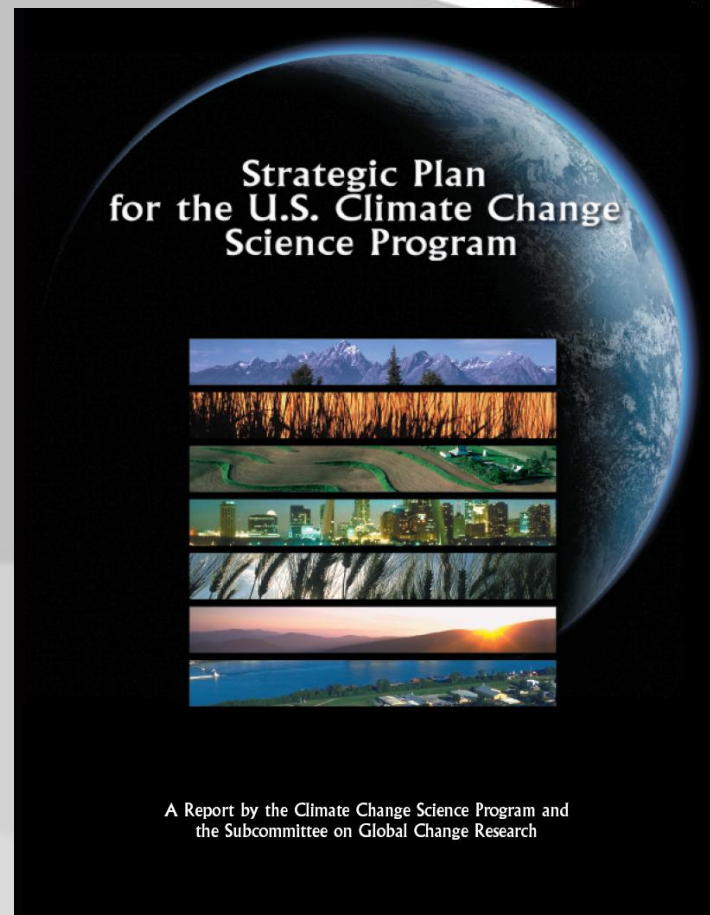
Science Questions and Focus Areas

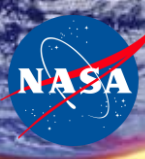




CCSP Goals [from 2003 Strategic Plan]

1. Improve knowledge of climate and environment.
2. Improve quantification of forces driving changes to climate.
3. Reduce uncertainty in projections of future climate change.
4. Understand sensitivity and adaptability of natural and manmade systems.
5. Explore uses and limits of managing risks and opportunities.





NASA ESD's Products for the Nation and the World

■ Scientific Knowledge

- Discovery
- Process Knowledge
- Trend Detection and Attribution
- Forecasting Capability

■ Applications to National and Global Needs

- Environmental Policy
- Resource Management
- Forecasting and Assessment
- Decision-Making by Public and Private Sectors
- Disaster Characterization and Response

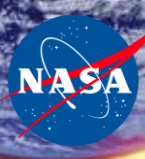
■ Technical Capability for Space and Airborne Science

■ Environmental Data for National and Global Use

■ Positive Examples of International Cooperation

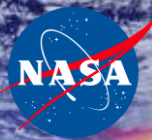
■ Trained Workforce for Science and Technology

■ A Better-Informed and Inspired Public



NASA ESD's Products for the Nation and the World

- ✓ Scientific Knowledge
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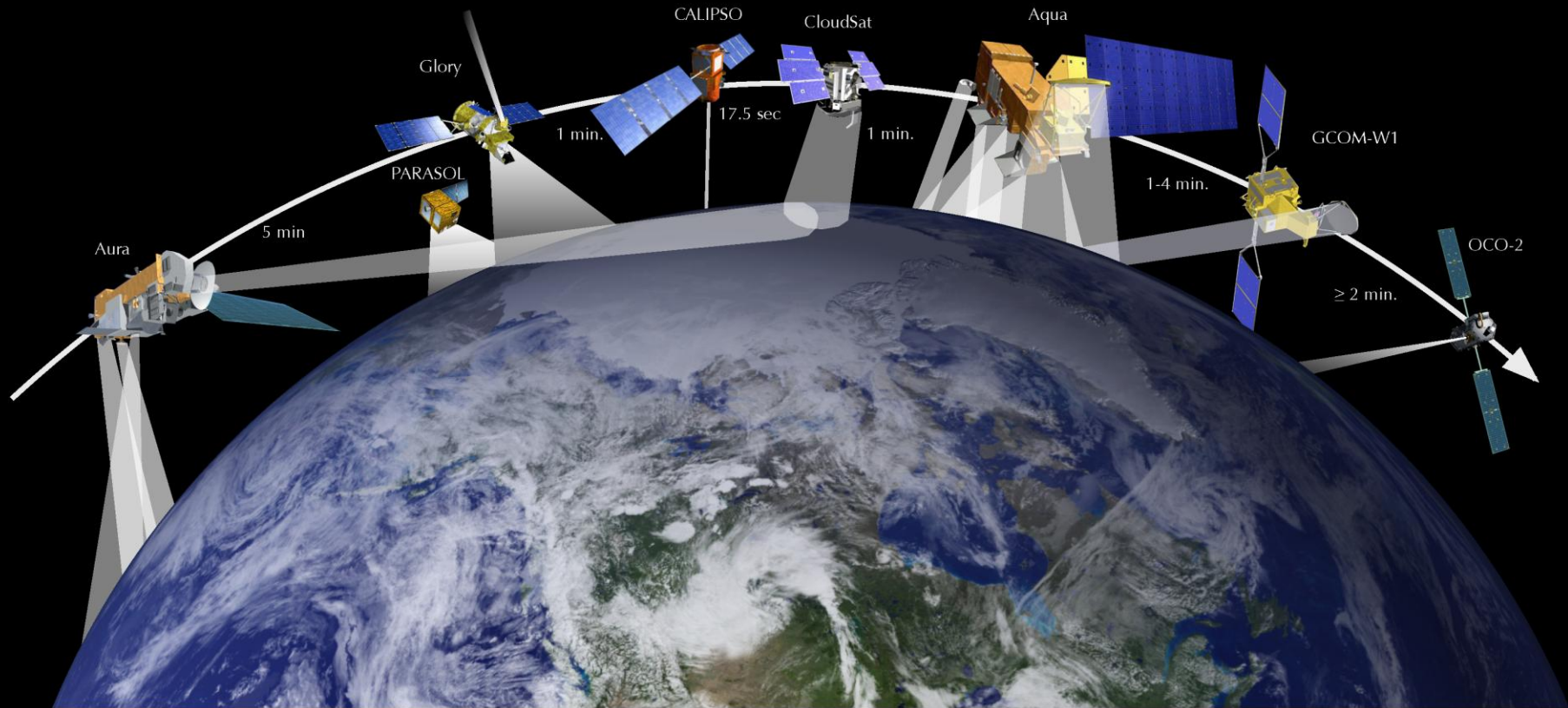
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NASA Operating Earth Science Satellites – with International Partners



The Afternoon Constellation "A-Train"



The Afternoon Constellation consists of eight U.S. and international Earth Science satellites that fly within approximately ten minutes of each other to enable concurrent science. The joint measurements provide an unprecedented sensor system for Earth Observations.

04/06/10



United States



Brazil



Canada



Finland



France



Japan



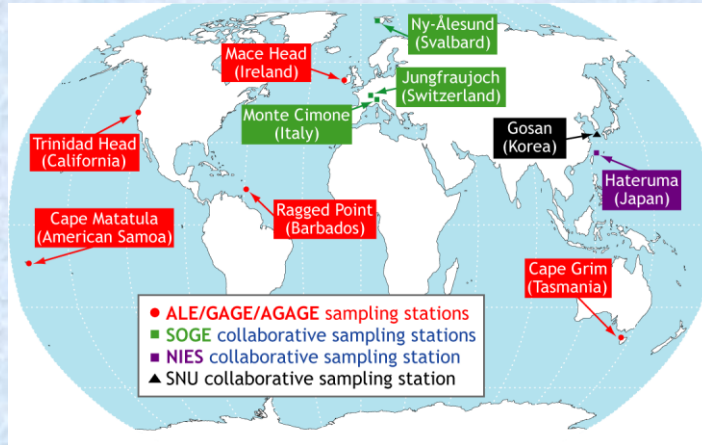
Netherlands



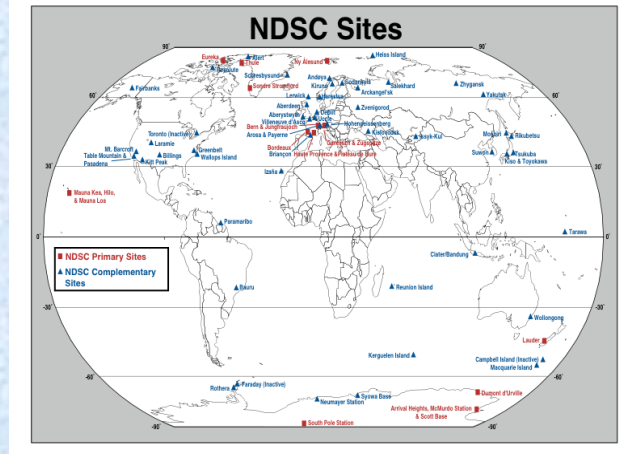
United Kingdom

Examples of NASA-Supported Ground Networks

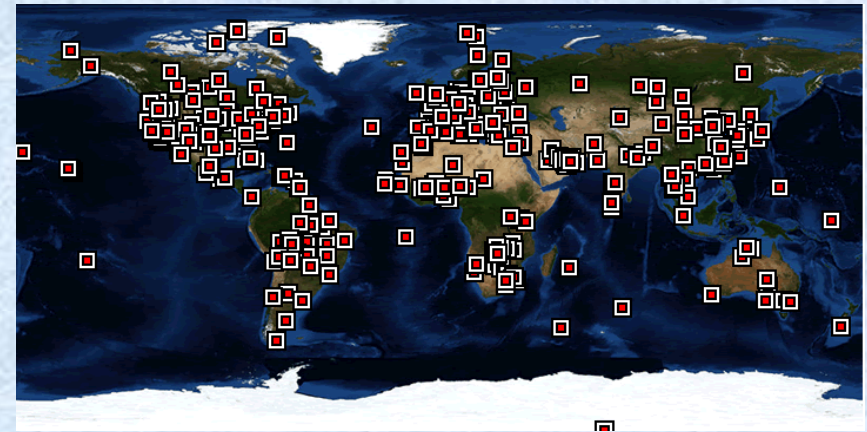
AGAGE



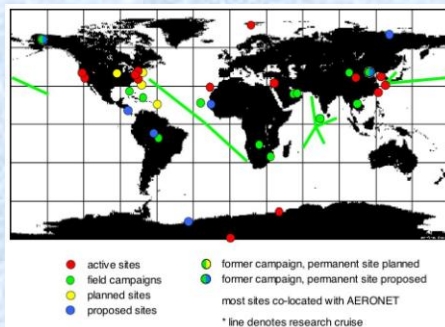
NDACC



AERONET



ILRS



MPLNet



TCCON

Airborne Science Program

Observing Platforms for Earth System Science Investigations



WB-57



Global Hawk



ER-2



G III



Learjet



DC-8



Ikhana



P-3



S-3B



B-200

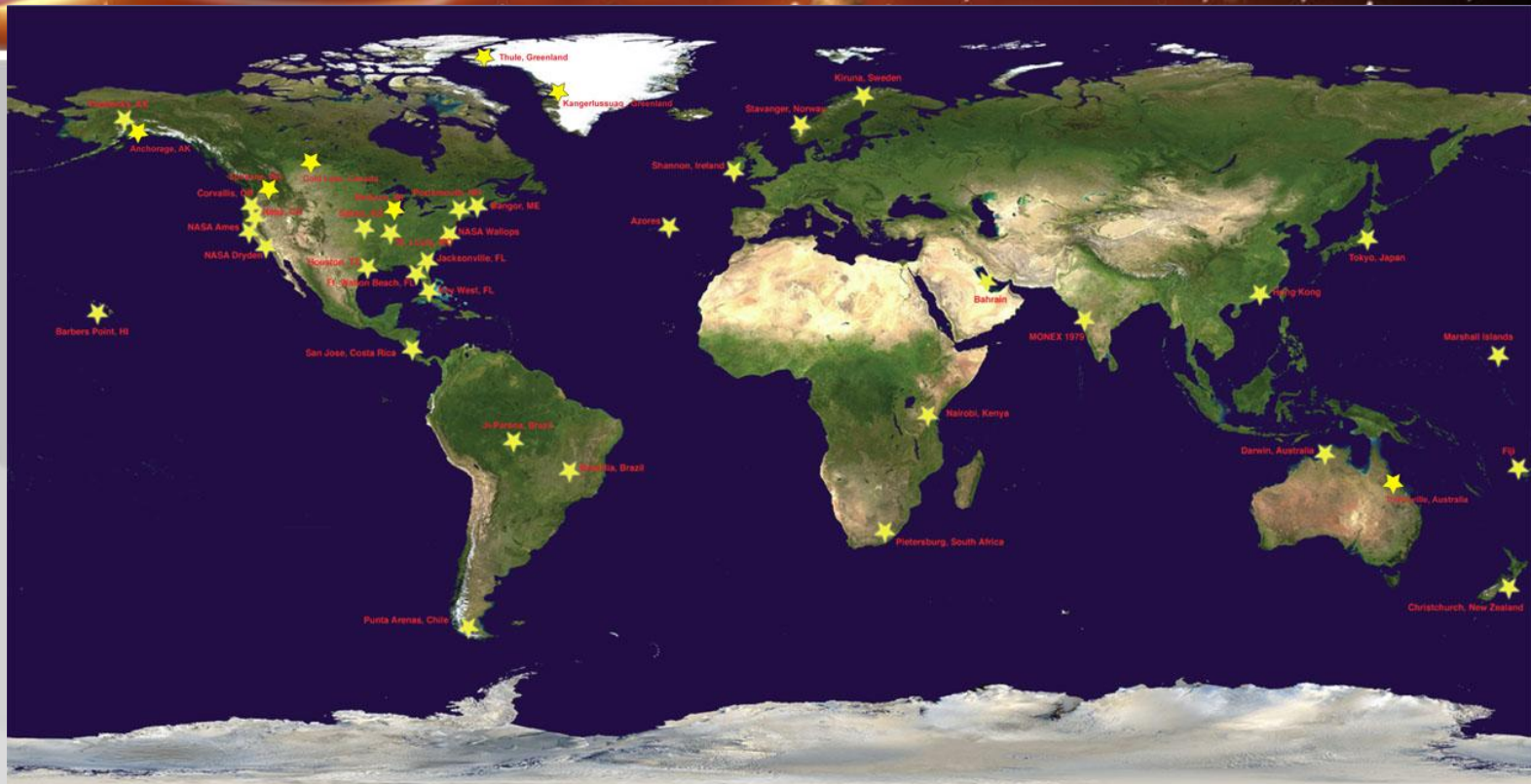


Twin Otter



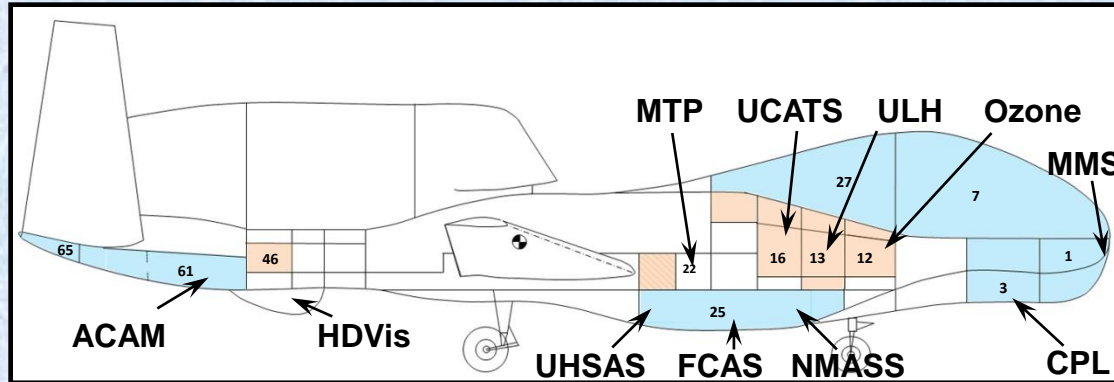
SIERRA

Airborne/Suborbital Campaigns Provide Global Access to Regional Processes

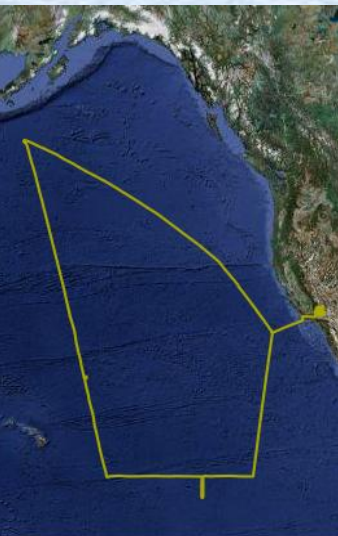


- Satellite/Space Data Product Calibration/Validation & Algorithm Development
- Process Studies & Model Validation
- Applications Development & Demonstration
- Space Sensor and Remote Sensing Technology Development & Demonstration
- Future capability for focused observations of persistent but finite phenomena and hazardous operations (UAVs)

GloPac Mission – Spring, 2010



ACAM	Airborne Compact Atmospheric Mapper (GSFC)	Cross-track scanning spectrographs of NO ₂ , O ₃ , & aerosols.
CPL	Cloud Physics LIDAR (GSFC)	Backscatter LIDAR for hi-res profiling of clouds & aerosols.
FCAS	Focused Cavity Aerosol Spectrometer (U. of Denver)	Aerosol size and concentration measurements.
MMS	Meteorological Measurement System (ARC)	Science quality aircraft state variable measurements.
MTP	Microwave Temperature Profiler (JPL)	Passive microwave radiometer meas. of O ₂ thermal emissions.
HDVis	HiDef Video System (ARC)	Time-lapse nadir color digital imagery with georeferencing.
NMASS	Nuclei-mode Aerosol Size Spectrometer (U. of Denver)	Aerosol size and concentration measurements.
Ozone	UAS Ozone (NOAA)	Dual-beam UV photometer for accurate O ₃ measurements.
UCATS	UAS Chromatograph for Atmospheric Trace Species (NOAA)	Dual gas chromatographs for N ₂ O, SF ₆ , H ₂ , CO, & CH ₄ meas.
UHSAS	Ultra-High Sensitivity Aerosol Spectrometer (Droplet Measurement Technologies)	Ultra-high sensitivity aerosol spectrometer.
ULH	UAS Laser Hygrometer (JPL)	In-situ hi-accuracy atmospheric water vapor measurements.



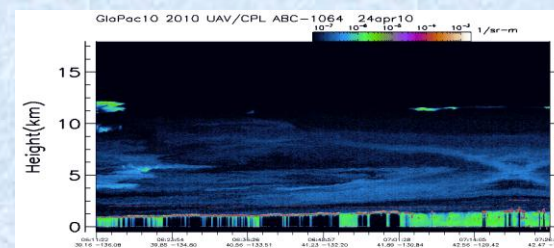
April 13th
24.3 hrs, 8000nmi,
62300 ft



April 23rd
28.6 hrs, 9700nmi,
65200 ft



Average CPL-derived Asian dust (altitude 2-10 km) observed south of Alaska has optical depth is 0.04





GRIP* Accomplishments

Scientific Accomplishments

Tropical Cyclone Genesis

- Tropical Storm Gaston—a “null” case for development
- Hurricane Karl—unprecedented multiday coverage from first detection through genesis

Rapid Intensification

- Hurricane Earl—documentation of rapid intensification as well as weakening of a large Category 5 storm
- Hurricane Karl—observations of rapid intensification from storm stage to Category 3 and landfall

Technical Accomplishments

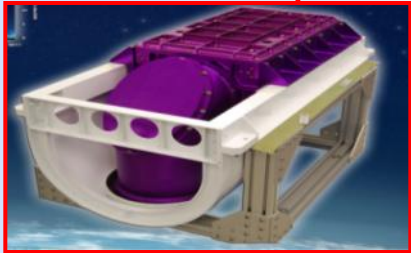
Hurricane Earl

- First Global Hawk flight over a hurricane

Hurricane Karl

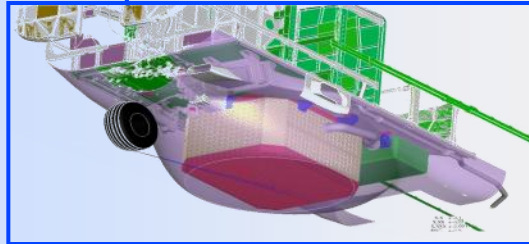
- 20 crossings of eye of Hurricane Karl by Global Hawk
- Close flight coordination of:
 - Global Hawk
 - DC-8
 - WB-57
 - NOAA G-IV & P-3's
 - NCAR G-V, and
 - Air Force C-130J's

Stimulus-Funded Technology Development Global Hawk Instruments



Land, Vegetation, & Ice Sensor (LVIS)

This task will integrate the LVIS capability onto the Global Hawk and provide an automated, reliable package for high altitude measurements.



Global Ozone Lidar Demonstrator (GOLD)

GOLD will enable, for the first time, Ozone LIDAR measurements from a high-altitude aircraft that supports global atmospheric composition and climate change investigations.



UAVSAR

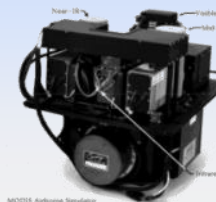
The Uninhabited Aerial Vehicle – Synthetic Aperture Radar (UAVSAR) project will install two existing UAVSAR pods on the long-range, high-endurance UAV. On Global Hawk, UAVSAR will generate precise topographic maps and single-pass polarimetric interferograms of ice and vegetation.



Stimulus-Funded Development: Facility Class Instruments

Enhanced MODIS Airborne Simulator (eMAS)

This task will replace major subsystems on the MAS to extend its service life, increase reliability and improve data. The task will also increase spectral coverage, resolution, and calibration accuracy. The upgraded MAS will fly on the NASA ER-2.

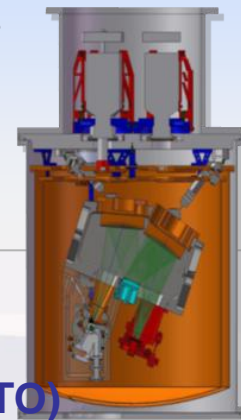


Portable Remote Imaging Spectrometer (PRISM)

PRISM will be a UV-NIR (350 to 1050 nm) spectrometer capable of airborne measurements from a variety of platforms. PRISM will be particularly optimized for coastal ocean measurements, with unprecedented sensitivity across the large range of coastal reflectance. PRISM will be test flown on the DHC-6 Twin Otter.

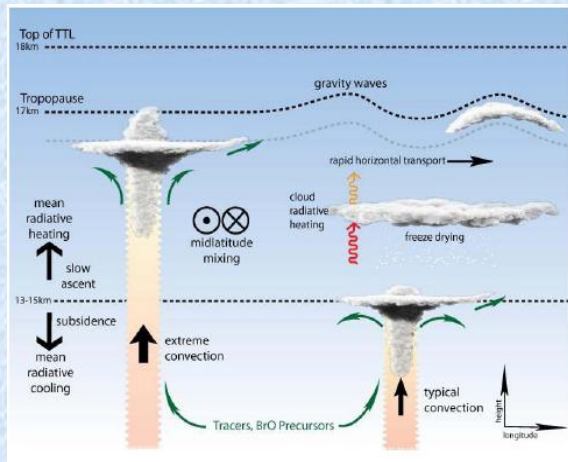
Next Generation Airborne Visible InfraRed Imaging Spectrometer (AVIRISng)

This next generation AVIRIS-class imaging spectrometer will help continue measurements of upwelling spectral radiance and support the HypSIRI Decadal Survey mission. Several new subsystems will help AVIRISng to achieve a factor of two improvement in SNR and spectral resolution relative to AVIRIS, as well as significant reductions in mass and volume for future flights on the DHC-6 Twin Otter.



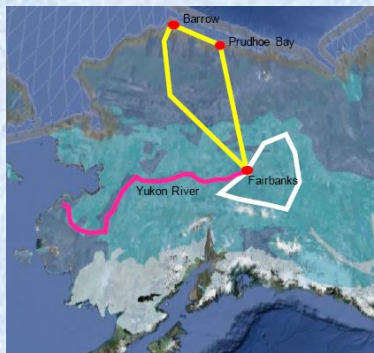
NASA ANNOUNCES FIRST SELECTION OF FIVE 'EARTH VENTURE' RESEARCH MISSIONS

Maximum \$150 million total funding ceiling



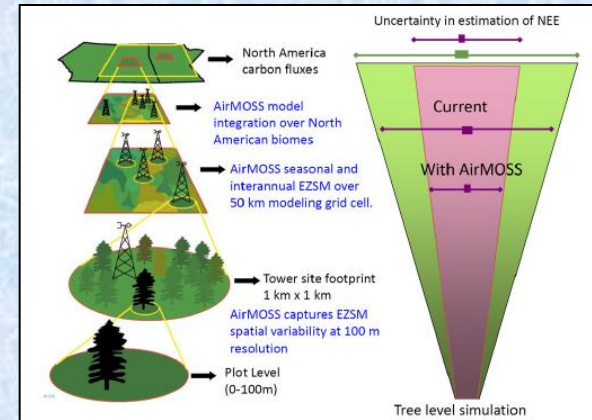
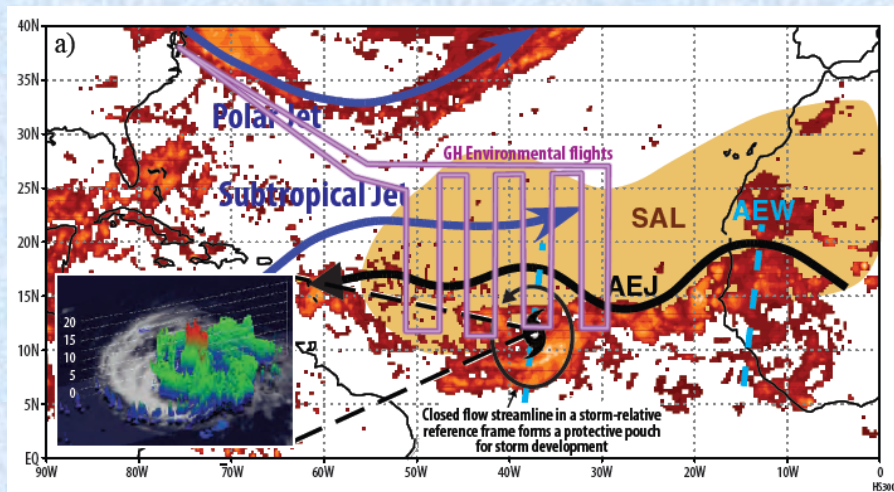
Above: Airborne Tropical Tropopause Experiment: will improve understanding of the processes that control the flow of atmospheric gases into this region by studying chemical and physical processes at different times of year.

Below: Carbon in Arctic Reservoirs Vulnerability Experiment: investigations into Arctic carbon cycling.



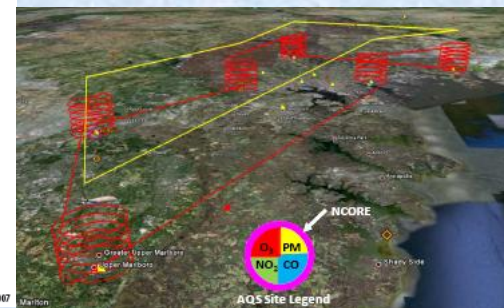
NASA's Earth Venture missions, part of the Earth System Science Pathfinder program, are small, targeted science investigations. They complement larger research missions and were recommended by the National Research Council Decadal Survey as quick-turnaround projects. This year's selections are all airborne investigations. Future Venture proposals may include small, dedicated spacecraft and instruments flown on other spacecraft.

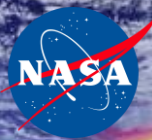
Below: Hurricane and Severe Storm Sentinel: will investigate hurricanes intensity change processes in the Atlantic Ocean basin.



Above: Airborne Microwave Observatory of Subcanopy and Subsurface: will address the uncertainties in gas exchange estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems.

Below: Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality

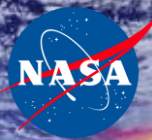




ESD Research Solicitations in ROSES

- ESD Research is solicited via the annual SMD Omnibus Solicitation “Research Opportunities for Space and Earth Sciences (ROSES)”
- ROSES 2009 had 26 elements actively competed, for which selection of 21 has been completed (as of end of August 2010). Statistics so far:
 - Total number of proposals received: 1574
 - Selection rate to date: 33%
 - Percentage of selected PIs at NASA/JPL: 31%
 - Average task size: \$300K/year (\$213K if leave out EV-1)
 - Mean time to selection (weighted) – 209 days
- ROSES 2010 (released February, 2010) covering period 4/30/10-4/30/11 includes 25 actively solicited “elements” covering research, applied sciences, technology, and data management. Elements with recent or near-term due dates include:

– Enhancing the Capability of Comp. Earth System Models and NASA Data (A.24)	9/17/10
– Recompetition of the GRACE Science Team (A.23)	9/24/10
– Atmospheric Composition: Modeling and Analysis (A.14)	10/1/10
– Earth Surface and Interior (A.19)	10/1/10
– Ocean Salinity Science Team (A.8)	10/29/10
– Applications of Geodetic Imaging (A.21)	11/1/10
– Advanced Concepts in Space Geodesy (A.20)	12/1/10
– NASA Energy and Water Cycle Study (A.17)	TBD



Training Next Generation of Scientists and Citizens

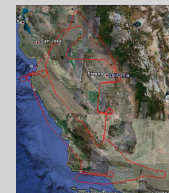
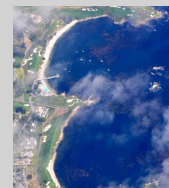
- NASA Earth Science operates or contributes to several activities in support of training future scientists and citizens
 - Global Learning and Observations to Benefit the Environment (GLOBE) – students around the world make observations using protocols provided by scientists and exchange data
 - 111 active international partners and 136 domestic partners in the U.S.A.
 - Worldwide Student Climate Research Campaign to be launched in fall 2011



The **GLOBE** Program



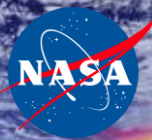
- Student Airborne Research Program (SARP) – experiential summer program where ~30 students from around the country carry out experiments on DC-8 using MASTER and Whole Air Sampler – for atmosphere, ocean, and land studies



- DEVELOP

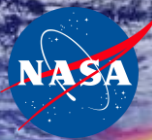
- Student-staffed, scientist-advised projects using NASA observations to address societally-relevant issues designed to grow workforce for incorporating satellite data into decision-making (see poster today!)





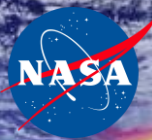
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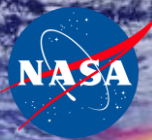
The Bigger Perspective

- Significant external attention is being placed on utilizing climate information to inform studies of impacts, adaptation, mitigation, and vulnerability
- NRC report (2009) on US Global Change Research Program suggested significant changes in interagency climate program (*Restructuring Federal Climate Research to Meet the Challenges of Climate Change*)*
- US Global Change Research Program issued assessment report *Global Climate Change Impacts in the United States* (May, 2009)
- US National Research Council addressed all of these in its 2010 report series *America's Climate Choices*
 - Advancing the Science of Climate Change
 - Adapting to the Impacts of Climate Change
 - Limiting the Magnitude of Climate Change
 - Informing an Effective Response to Climate Change
- US Global Change Research Program held Climate Adaptation Summit in May, 2010 (report issued 9/10)
- US Climate Change Adaptation Task Force issued report (10/5/10)
- International Council for Science (ICSU) released report *Regional Environmental Change: Human Action and Adaptation - What does it take to meet the Belmont Challenge?* (Sept., 2010)*



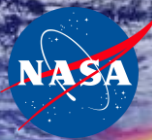
From *Global Climate Change Impacts in the United States* (USGCRP, 2009)

- Report included a section on “An Agenda for Climate Impacts Science:” “The focus below, however, is on advancing our knowledge specifically on climate change impacts and those aspects of climate change responsible for these impacts in order to continue to guide decision making”
 - Expand our understanding of climate change impacts.
 - Ecosystems
 - Economic systems, human health, and the built environment
 - Refine ability to project climate change, including extreme events, at local scales.
 - Expand capacity to provide decision makers and the public with relevant information on climate change and its impacts.
 - Improve understanding of thresholds likely to lead to abrupt changes in climate or ecosystems.
 - Improve understanding of the most effective ways to reduce the rate and magnitude of climate change, as well as unintended consequences of such activities.
 - Enhance understanding of how society can adapt to climate change.



NRC Review of USGCRP (2009): Top Priorities

- Reorganize the program around integrated scientific-societal issues to facilitate crosscutting research focused on understanding the interactions among the climate, human, and environmental systems and on supporting societal responses to climate change.
- Establish a U.S. climate observing system, defined as including physical, biological, and social observations, to ensure that data needed to address climate change are collected or continued.
- Develop the science base and infrastructure to support a new generation of coupled Earth system models to improve attribution and prediction of high-impact regional weather and climate to initialize seasonal-to-decadal climate forecasting, and to provide predictions of impacts affecting adaptive capacities and vulnerabilities of environmental and human systems.
- Strengthen research on adaptation, mitigation, and vulnerability.
- Initiate a national assessment process with broad stakeholder participation to determine the risks and costs of climate change impacts on the United States and to evaluate options for responding.
- Coordinate federal efforts to provide climate services (scientific information, tools, and forecasts) routinely to decision makers.



From America's Climate Choices: Advancing the Science of Climate Change

- **Conclusion 1:** Climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems.
- **Conclusion 2:** The nation needs a comprehensive and integrative climate change science enterprise, one that not only contributes to our fundamental understanding of climate change but also informs and expands America's climate choices.
 - This report identifies seven cross-cutting research themes, grouped into three general categories, that collectively span the most critical research needs for understanding climate change and for informing and supporting effective responses to it:

Research to Improve Understanding of Human-Environment Systems:

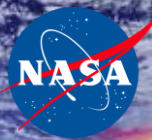
- 1) *Climate Forcings, Responses, Feedbacks and Thresholds in the Earth System*
- 2) *Climate-Related Human Behaviors and Institutions*

Research to Support Effective Responses to Climate Change:

- 3) *Vulnerability and Adaptation Analyses of Coupled Human-Environment Systems*
- 4) *Research to Support Strategies for Limiting Climate Change*
- 5) *Effective Information and Decision-Support Systems*

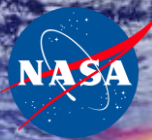
Tools and Approaches to Improve Both Understanding and Responses:

- 6) *Integrated Climate Observing Systems*
- 7) *Improved Projections, Analyses, and Assessments*



From America's Climate Choices: Advancing the Science of Climate Change, cont.

- *Recommendation 1:* The nation's climate change research enterprise should include and integrate disciplinary and interdisciplinary research across the physical, social, biological, health, and engineering sciences; focus on fundamental, use-inspired research that contributes to both improved understanding and more effective decision making; and be flexible in identifying and pursuing emerging research challenges.
- *Recommendation 2:* Research priorities for the federal climate change research program should be set within each of the seven cross-cutting research themes outlined above...
- *Recommendation 3:* The federal climate change research program ... should redouble efforts to develop, deploy, and maintain a comprehensive observing system that can support all aspects of understanding and responding to climate change.
- *Recommendation 4:* The federal climate change research program should work with the international research community and other relevant partners to support and develop advanced models and other analytical tools to improve understanding and assist in decision making related to climate change.
- *Recommendation 5:* A single federal interagency program or other entity should be given the authority and resources to coordinate and implement an integrated research effort that supports improving both understanding of and responses to climate change...
- *Recommendation 6:* The federal climate change research program should be formally linked with action-oriented response programs focused on limiting the magnitude of future climate change, adapting to the impacts of climate change, and informing climate-related actions and decisions...
- *Recommendation 7:* Congress, federal agencies, and the federal climate change research program should work with other relevant partners ...to expand and engage the human capital needed to carry out climate change research and response programs.



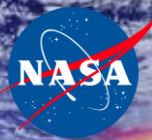
Report from USGCRP Climate Adaptation Summit

■ Conclusions from Report:

- The United States' response to climate change must include adaptation as well as mitigation.
- The current suite of federal adaptation activities and plans lacks clear organization and is confusing to potential state, regional, and local partners and other stakeholders.

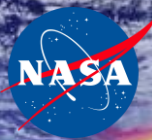
■ Seven priorities for near-term action were identified:

- Developing an overarching national strategy to guide federal climate change adaptation programs.
- Improving coordination of federal plans and programs.
- Creating a federal climate information portal.
- Creating a clearinghouse of best practices and toolkits for adaptation.
- Including support for assessment in USGCRP agency budgets.
- Increasing funding for research on vulnerability and impacts, including economic analyses, and pilot projects that join local, state, and regional governments and academic institutions to develop and test adaptation measures and tools.
- Initiating a regional series of ongoing climate adaptation forums.



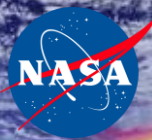
From Interagency Climate Change Adaptation Task Force

- Summary of Policy Goals and Recommended Actions for the Federal Government
 - Encourage and Mainstream Adaptation Planning across the Federal Government
 - Improve Integration of Science into Decision Making
 - Address Key Cross-Cutting Issues
 - Improve water resource management in a changing climate
 - Protect human health by addressing climate change in public health activities
 - Build resilience to climate change in communities
 - Facilitate the incorporation of climate change risks into insurance mechanisms
 - Address additional cross-cutting issues
 - Enhance Efforts to Lead and Support International Adaptation
 - Coordinate Capabilities of the Federal Government to Support Adaptation



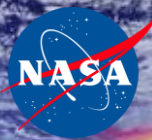
From ICSU “Belmont Challenge” Report

- The Belmont Challenge: “... a challenge for the international scientific community to *develop and deliver knowledge in support of national and international government action to mitigate and adapt to global and regional environmental change with an emphasis on regional hazards.*”
- *Urgent needs identified by the panel:*
 - Coordinate efforts and enhance the support required to address the needs of a sustainable environment and the needs of society. The challenge is to integrate environmental and developmental issues that have often been addressed independently in past decades.
 - Facilitate the dialogue between scientists, decision makers and the general public to support decisions and actions at the forefront of society’s needs.
 - Encourage natural and social scientists to work together to ensure that environmental observations, analyses, predictions and services most effectively meet the needs of society.
 - Maintain and expand access to, and use of, the current global observing and monitoring systems through coordinated databases and develop assimilation procedures to achieve the maximum benefit.
 - Respond to society’s increasing demand for detailed information at the regional and local scales. This requires sector-relevant information that includes observations, analyses, high-resolution projections/predictions at timescales from days to decades.



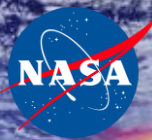
NASA Earth Science Program Evolution

- Cooperative activity initiated in FY09 between ESD and Environmental Management Division in Office of Infrastructure studying impacts of climate variability and change on NASA centers.
- Carbon Monitoring System (CMS) activity initiated in FY10 in response to Congressional direction to produce products on fluxes and stores of carbon in the Earth system. Initial emphases
 - Production of “pilot products” on terrestrial biomass (US-focused) and global integrated emission/uptake (“flux”)
 - Scoping study initiated (July, 2010 workshop) to look at how to utilize future NASA observations most effectively for improving future products (in context of other observations)
 - CMS Science Definition Team (SDT) ROSES element just released, with proposals due 12/17/10
- NASA is beginning to invest in USGCRP National Climate Assessment (NCA) beginning in FY11 to support both development of 2013 statutory requirement for quadrennial assessment and longer-term sustained assessment capability for the nation
- Applied Sciences program is evolving – initial presentation made to Applied Science Analysis Group (Oct 21-22), which will be further discussed at upcoming meeting of Earth System Subcommittee.



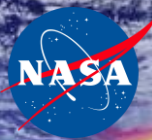
Conclusion: The A-Train Role in Meeting the Greater Challenge

- A-Train will remain a centerpiece of the global observing system for the foreseeable future and demonstrates value of constellations in development of the observing system of the future
- A-Train observations will contribute towards enhanced modeling (initialization, assimilation, verification, process representation) needed to deal with regional changes and provide guidance for adaptation and mitigation measures (e.g., carbon and albedo management policies)
- A-Train observations will contribute directly for several areas of climate-related societal interest (e.g., air quality) as well as for other areas (e.g., disaster management)
- A-Train observations and analysis will continue to be key to an increasing range of international and national assessments
- A-Train provides fertile data set for training of next generation of interdisciplinary climate scientists
- A-Train's international origins will serve as example of our ability to cooperate synergistically for common good
- A-Train scientists can work increasingly closer with others (e.g., social scientists) to enhance use and application of data



Conclusions

- NASA's Earth Science Program has involved a sustained, long-term effort to understand the Earth system through a mix of satellite, surface-based, airborne, laboratory, and computational efforts.
- A-Train has been an outstanding success in providing for integrated multi-national synergistic study of the Earth system, its evolution, the forcings that act upon it, and the mechanism by which it responds to change
- Increasing societal interest in climate impacts, adaptation, vulnerability, mitigation, and assessment are driving broader national interagency program, and NASA is responding by evolving its program while maintaining traditional focus on advancing Earth system science
- The A-Train will be an important contributor to all aspects of NASA's scientific studies and will inform policy and decision-making on national and international levels



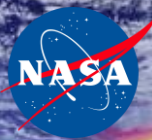
From Report of Ocean Policy Task Force

■ National Priority Objectives

- Ecosystem-Based Management
- Coastal and Marine Spatial Planning
- Inform Decisions and Improve Understanding
- Coordinate and Support
- Resiliency and Adaptation to Climate Change and Ocean Acidification
- Regional Ecosystem Protection and Restoration
- Water Quality and Sustainable Practices on Land
- Changing Conditions in the Arctic
- Ocean, Coastal, and Great Lakes Observations, Mapping, and Infrastructure

■ The National Goals of Coastal and Marine Spatial Planning

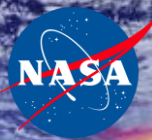
- Support sustainable, safe, secure, efficient, and productive uses of the ocean, our coasts, and the Great Lakes, including those that contribute to the economy, commerce, recreation, conservation, homeland and national security, human health, safety, and welfare;
- Protect, maintain, and restore the Nation's ocean, coastal, and Great Lakes resources and ensure resilient ecosystems and their ability to provide sustained delivery of ecosystem services;
- Provide for and maintain public access to the ocean, coasts, and Great Lakes;
- Promote compatibility among uses and reduce user conflicts and environmental impacts;
- Improve the rigor, coherence, and consistency of decision-making and regulatory processes;
- Increase certainty and predictability in planning for and implementing new investments for ocean, coastal, and Great Lakes uses; and
- Enhance interagency, intergovernmental, and international communication and collaboration



CCSP Internal Organization*

- Atmospheric Composition
- Climate Variability and Change
- Modeling
- Global Water Cycle
- Land Use and Land Cover Change
- Global Carbon Cycle
- Ecosystems
- Human Contributions and Responses
- Observing and Monitoring the Climate System
- Data Management and Information
- Communications
- International Research and Cooperation
- Education

* This internal structure of the CCSP continued with little change through its conversion back to the USGCRP in 2009.



Examples of LIDAR Use in NASA Major Airborne Field Campaigns

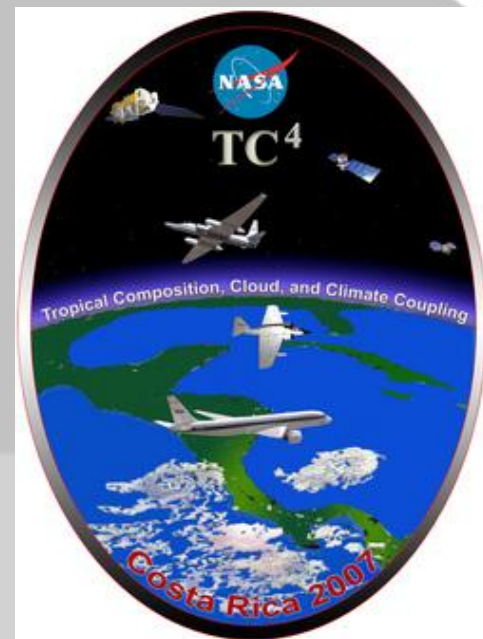
NASA African Monsoon Multidisciplinary Analyses (NAMMA)



LASE instrument flew on DC-8 - 2006



The HSRL and DIAL instruments flew aboard the B-200 and EC-8, respectively, as part of ARCTAS in 2008



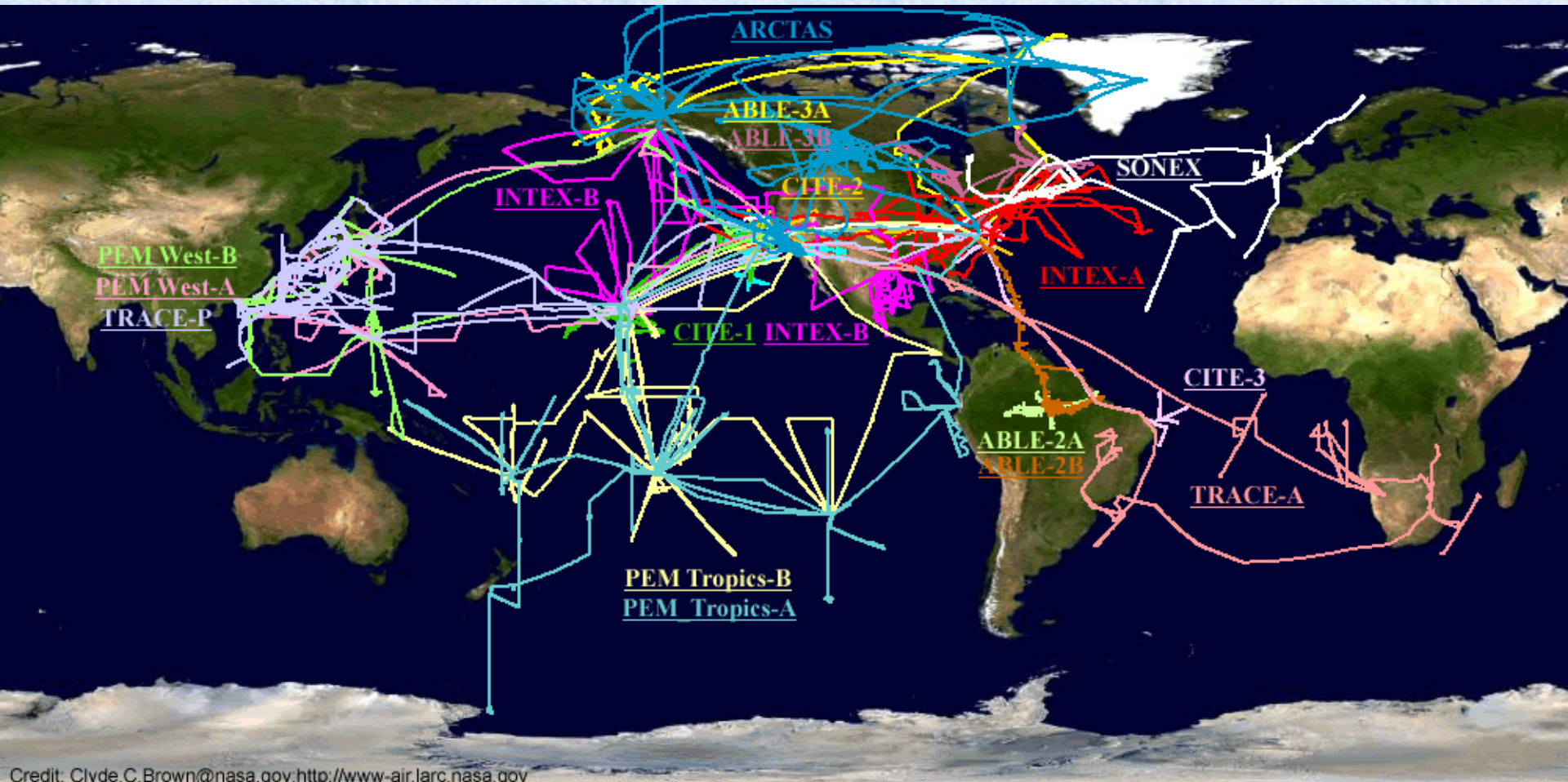
The DIAL, LASE, and CPL instruments flew aboard the DC-8 (DIAL, LASE) and ER-2 instruments in the TC4 campaign in 2007

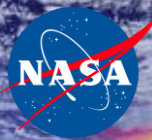
The CPL instrument flew aboard the ER-2 in CRYSTAL-FACE in 2002



The DIAL and HSRL instruments flew in INTEX-B aboard the DC-8 and B-200, respectively, in 2006

NASA Tropospheric Chemistry Field Campaigns (1983-2008)





End-to-end Support in a Globally Integrated Program



Airborne Sensors



Research Balloons



Uninhabited Aerial Vehicles



Field Campaigns



Ground Networks



Research Vessels



Ground Stations

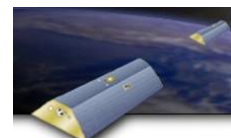
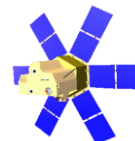
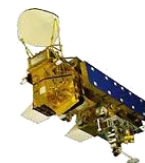
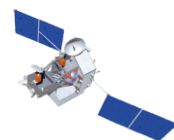


Ground Stations

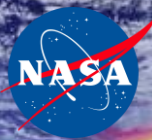


Research Balloons

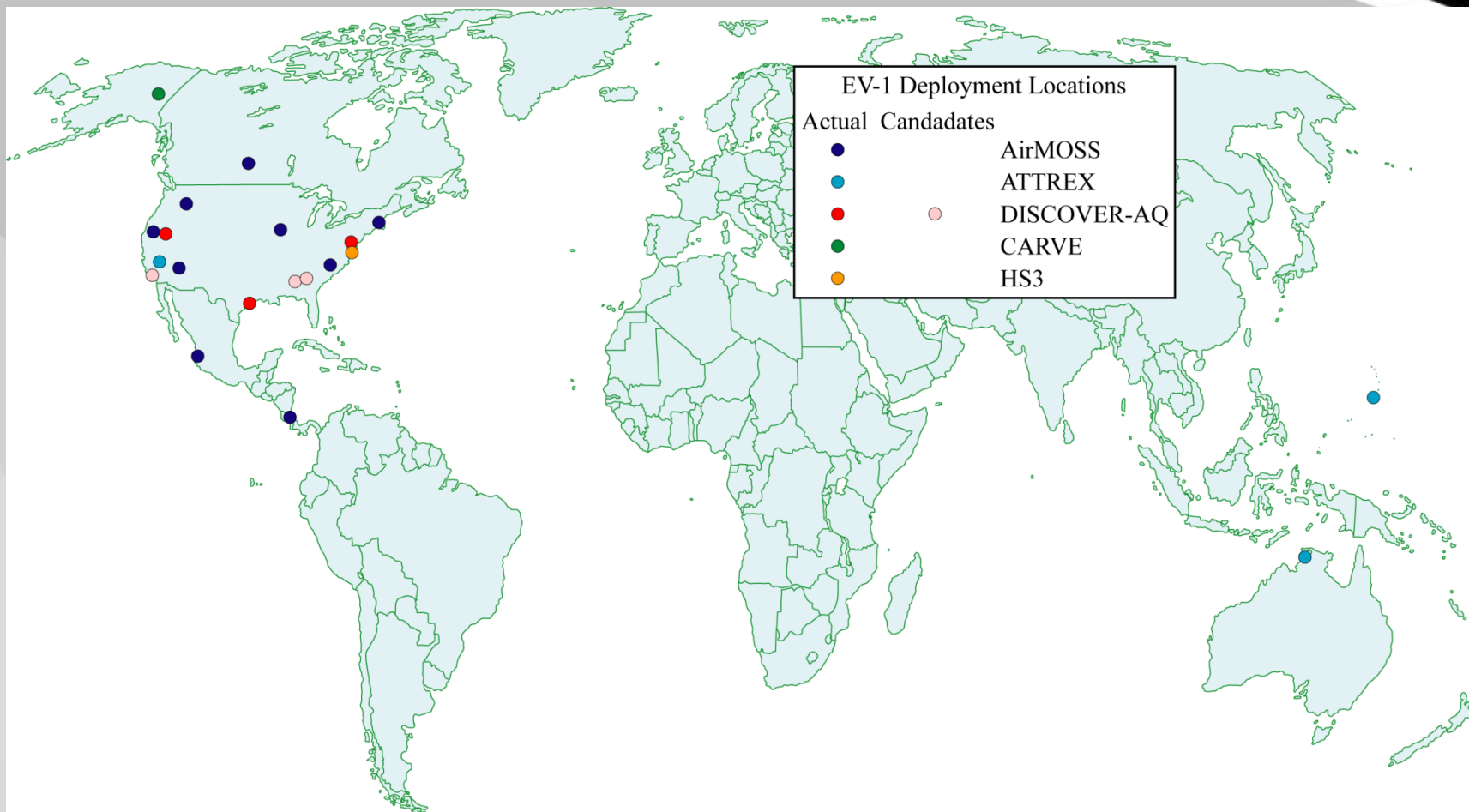
Space-based: Sensors & Data Relay



NASA's & Partners' ground, sea, air and in-situ measurements augment space-based observations to validate science results and provide complimentary measurements



Deployment Locations of EV-1 Missions



SARP 2010 DC-8 Science Flights



- 28 Students participating this year
- Conducted 2 Science flights on the DC-8



Flight at 1000 ft
AGL over
commercial dairy
farm operations



Direct sampling
with the Whole Air
Sampler